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"Materials Processing and Manufacturing Technologies for Diamond Substrates Mutlichip Modules"

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Overview

In this quarter we have

® continued our baseline program to optimize the throughput of diamond in conventional chemistries,

® fabricated and installed modifications to the AX6600 substrate stage and microwave transmission line to couple and remove higher power levels,

® initiated work on release techniques using novel materials for production of free standing 6" diameter diamond without necessitating a wet-etch process to remove silicon substrates,

® and begun construction of a thermal conductivity test stand for quality measurements on free standing diamond films.

75kW Reactor

In previous quarters, we have reported that AX6600 reactor operations have become routine, with 40-45 kW operation proceeding around the clock. Our goal during this time frame was to scale up operations to full (75kW) power and continue with deposition studies at this power level.

Microwave transmission line modifications were installed which reduced the reflected power to about 1%, allowing full power transmission and coupling to the plasma. At these low reflected powers, the heating of wave guide components is minimal, and the reliability and MTBF of these components is optimized.

The substrate mounting stage was redesigned to maintain a flatter profile under high heat flux while providing better cooling and better temperature control to the substrate. These modifications (previously reported fabricated and pre-assembled) were successfully installed and tested during this quarter. Higher power operations were attained, albeit only briefly above 60kW as additional cooling requirements were identified. These requirements resulted in further design refinements. Fabrication of modified components is scheduled for early April 1994.

The 75kW transmitter modifications have proven extremely successful, with robust power control and improved filament life resulting from optimizing the control systems.

Process Transfer, Ongoing Experiments

We have continued to develop diamond growth process in conventional (H_2, CH_4, O_2) chemistries from our prototype to the 75kW reactor. Operation at 40-45 kW with lower reflected power scales as projected to yield throughputs in the 500 mg/hr range.

We have undertaken to develop a technique for releasing the diamond film from the substrate after deposition without necessitating a wet-etch of the substrate. In addition to eliminating the use of hazardous chemicals, this further reduces the cost of the diamond film by eliminating the use of expendable substrates. Furthermore, our experience suggests that a significant portion of the wafer bow is due to the thermal expansion mismatch between the substrate and the film, and that this bowing is relieved during cool down with a substrate which releases the film. Successful substrate releases have been run in the prototype reactor on molybdenum up to 3" diameter. Runs on the AX6600 using both molybdenum and other novel materials have commenced. A novel

material has successfully released the diamond sample on 1" diameter test coupons. Studies are continuing on 6" and 8" molybdenum and other modified materials.

Thermal Probe

We have purchased the design of an existing thermal conductivity test stand. This design uses the thermal wave technique for a noise immune "phase-lag" measurement of the in-plane thermal diffusivity. The use of an existing and proven design will allow faster time to full operation and utility in the MCM program, and better bench marking with other measurement techniques. The long lead items have been ordered, and fabrication of custom components begun.

Reactor Prototype Related Studies

We are continuing to study high growth rate (HGR) process in our PDS19 reactor, the prototype for the 75kW system, operating at 8kW and 2.45 GHz. Recent efforts have concentrated on design and testing of real-time temperature control hardware utilizing novel substrate mounting pucks and stage modifications. The size and shape of the substrate puck are crucial in that they interplay subtly with both the plasma and deposition effects as well as the heat removal profile. The results to date have scaled very successfully to the full sized designs in the AX6600, and have resulted in better substrate cooling, improved temperature uniformity, and real-time temperature control.

Reactor Modeling

The 2D modeling, using the GEM code, has been used quite extensively in the design of the stage rebuild as well as the substrate mounting puck modifications. The present version of the GEM code, which calculates the self-consistent electromagnetic and neutral particle effects, predicts the 2D profiles of all fields and particles of a hydrogen discharge. From this, the atomic hydrogen flux on the substrate can be calculated, and the profile optimized for uniformity and efficiency.

The success of the 2D code has been used to model possible alternate reactor geometry's for future development. Several such systems are of great interest:

® A compact 75kW system, with a single mode cavity, lower cost, and reduced substrate diameter,

® A modified reactor geometry with higher plasma area utilization,

® A larger scale system at lower frequency (around 250 MHz) and several hundred kW microwave power.

The continuing efforts on modeling are concentrating on further understanding and improving process on the 75kW system. As a support tool, the modeling is generally helping to determine ideal substrate mounting configurations and run conditions.